REPORT OF
NSF COMMITTEE OF VISITORS to EF

Date of COV: September 11-13, 2006
Division: Division of Emerging Frontiers
Directorate: Directorate for Biological Sciences
Number of actions reviewed by COV[1]: 165 **Awards:** 61 **Declinations:** 102 **Withdrawn:** 2
Total number of actions within Division during period being reviewed by COV[2]: Competitive proposal actions: 711 Awards: 187 Declinations: 524 Other:
Manner in which reviewed actions were selected: Proposals submitted to MicSeq, AToL, BIO Math, RCN, and FIBR are included in tables indicated to be *from jacket sample*. Data indicated as *from EIS* reflect **all** EF activities, not just the five that are the focus of this CoV. A random sample was examined, with jackets selected from each activity per year ***in proportion to*** the total number of jackets in these five activities for a total sample size of 153. Because there were varying numbers of proposals submitted to each of these five activities, the proportion of jackets in the random sample varies between activities. The COV added some jackets to the sample during its review (e. g., in BioMath). The sample contains representatives from all panels and all proposal solicitations. For qualitative measures (such as recommendation completeness), the sample provided sufficient data to provide examples of the styles and procedures of all of the programs and activities.

PART A. INTEGRITY AND EFFICIENCY OF THE DIVISION'S PROCESSES AND MANAGEMENT

A.1 Questions about the quality and effectiveness of the division's use of merit review procedures.

QUALITY AND EFFECTIVENESS OF MERIT REVIEW PROCEDURES	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
Is the review mechanism appropriate? (panels, ad hoc reviews, site visits)	Yes
Is the review process efficient and effective?	Yes
Are reviews consistent with priorities and criteria stated in the division's solicitations, announcements, and guidelines?	Yes

[1] To be provided by NSF staff.
[2] To be provided by NSF staff.

Do the individual reviews (either mail or panel) provide sufficient information for the principal investigator(s) to understand the basis for the reviewer's recommendation?	Yes
Do the panel summaries provide sufficient information for the principal investigator(s) to understand the basis for the panel recommendation?	Yes
Is the documentation for recommendations complete, and does the program officer provide sufficient information and justification for her/his recommendation?	Yes

Comments on the quality and effectiveness of the division's use of merit review procedures:
AToL: The merit review of the AToL proposals is extensive. In addressing the two criteria for NSF proposals (intellectual merit and broader impacts) all reviewers and panelists were asked to pay attention to the required components of an AToL project: (1) ambitious, large scale projects involving the necessary taxonomists, paleontologists, phylogeneticists, computer scientists, statisticians, or experts in genome sequencing to accomplish the proposed research; (2) a management plan that identifies personnel responsible for all major tasks, a time-table for research with annual milestones for judging productivity and progress, and plans for communication and coordination among researchers; and (3) if relevant, coordination with existing funded projects on similar research topics. The proposals for the program had at least 8 independent reviews and most had 10. Thus these proposals were every extensively reviewed both by the community at large via ad hoc reviews as well as by the panel members. Reviews, in general, were extensive and informative for the researchers. Deficiencies were pointed out and, often, potential solutions were suggested. All the reviews examined commented extensively on review criterion 1 and all commented (some less extensively) on review criterion 2. Panel Summaries commented on Broader Impacts especially and it is clear that successful proposals were convincing in review criterion 2. Most reviews also commented on the additional components (listed above) that are particular to this competition. Many of the funded proposals were resubmitted proposals which speaks to the effectiveness and thoroughness of the reviews. Funded proposals had uniformly Good to Excellent reviews.

Bio-Math, Research: The individual reviews as well as the panel summary are informative and, for the subset of proposals we were able to view, seemed to be consistent with the funding decision. However, for this group, the only jackets we were able to see were for proposals that were funded.

Bio-Math, UBM: In most cases, the individual reviews and panel summary were relatively consistent with one another, and portrayed the reasons for the decisions that were made. The reasons for awards as well as declines were particularly clear in the review analysis, even when they were less clear in the panel summary.

FIBR: FIBR proposals pose special challenges. They must be evaluated for their novelty and potential to address grand challenges in biology. However, their technical details must also receive careful scrutiny. The combination of ad-hoc reviewers, a multidisciplinary panel, and the participation of the program directors in the FIBR working groups seems ensure that this challenge is met. Site visits by program directors seem to be an effective mechanism to facilitate project evaluation, and for funded projects, to facilitate its success.
The review process appears to be efficient and effective.

Because FIBR proposals pose special challenges and the program is relatively new, reviewers sometimes evaluate them using standard criteria. This places a heavier responsibility on the ad-hoc panel and working group members. As members of the community become better informed about the nature of the FIBR program, the evaluation of FIBR proposals may become easier.

Individual reviews of FIBR project are detailed and thorough. We noted that, as is often the case, reviewers spent significantly more effort on the intellectual merit of the proposal and on details of implementation than on broader impacts. Overall, jackets contain adequate information to understand how decisions are made on proposals. However, in a noticeable subset of the panel summaries, there is not

enough critical discussion of strengths and weaknesses so that PIs will easily understand the basis for the funding decision. This detailed feedback is essential for those who may need to resubmit.

The documentation in the jackets does contain sufficient information for understanding funding decisions, however as stated above, principal investigator(s) may not always find that information in their panel summary. However, again, broader impacts seem not to be sufficiently emphasized (see following section: Questions concerning the implementation of the NSF Merit Review Criteria). The time to decision is appropriate. Approximately 70% of all FIBR proposals received a decision within 6 months.

RCN: While there was some variation over the fiscal years covered by this review, the use of panels was appropriate, involving both subject matter specific panels and RCN panels. The use of a general RNC panel is recommended as continuing oversight by a directorate-wide working group.

The process seems adequate for RCN; however, all reviewers need to be well aware of the specific review criteria. With several levels of review and administrative oversight it is extremely important to retain a timely response to PIs. The panel reviews seem to be the most important way to communicate with the PIs in this program.

Microbial Genome Sequencing: The awards made reflect a reasonable selection of sequencing projects. This program activity has emerged to provide an expansion in the knowledge base of biodiversity that is critically important to the fundamental understanding of life on Earth. While the core activity supported by Microbial Genome Sequencing was to expand the database of fully sequenced genomes of prokaryotic and eukaryotic microorganisms, the successful proposals presented and explained a context of importance for acquiring this information and providing it to the broader scientific communities. This kind of proposal required looking at research proposals in a different way than the standard, single investigator-initiated proposal. It also required, in some cases, redirecting reviewer focus from hypothesis-driven research questions to observational data acquisition that could open up new perspectives on the biological systems under study. In turn, the new perspectives have generated new hypotheses arising from enhanced understanding. This program activity has succeeded in getting the reviewer community to take a large-scale view in evaluation of MicGenSeq proposals. In aspects of technical competence to accomplish the proposed sequencing activity, the successful applicants teamed with well-established sequencing laboratories, facilities, or organizations, e.g. DOE and TIGR. Promotion of this type of collaboration did much to foster the formation of successful research teams. Successful proposals were sometimes distinguishable from declines by the strength of argument for the importance of the study, but more often by the perceived success potential for the research team or the quality of responses to the part B review criterion. The quality and quantity of discovery launched by this activity, really new discovery, is remarkable and impacts how we view life on earth and look for life on other planets.

The workload for program directors is such that making “timely” recommendations for funding likely pushes them into a punishing regimen of work that can endanger the quality of review and decision. This workload issue has not seemed to produce a negative influence on quality.

Recommendations:

AToL: The review process for the AToL proposals is considered exceptional both in the quantity and quality of reviews. This is exceptionally helpful to investigators in further developing successful projects. There are no data on the timing of review return to investigators for this particular program, but given the annual (instead of biannual) deadline for this competition, the 6 month return time is less critical and the Division is certainly close to the goal of 70% return within 6 months across the programs evaluated. Thus the recommendation is to continue the exceptional review process for the AToL proposals.

Continued attention needs to be paid to providing enough critical discussion of strengths and weaknesses in panel summaries for the PIs benefit. In addition, broad impacts must be sufficiently emphasized.

RCN: Need to more effectively inform reviewers of the special review criteria within the merit and broader impact framework.

A.2 Questions concerning the implementation of the NSF Merit Review Criteria (intellectual merit and broader impacts) by reviewers and program officers.

IMPLEMENTATION OF NSF MERIT REVIEW CRITERIA	YES, NO, DATA NOT AVAILABLE, or NOT APPLICABLE
Have the individual reviews (either mail or panel) addressed whether the proposal contributes to both merit review criteria?	Yes
Have the panel summary reviews addressed whether the proposal contributes to both merit review criteria?	Yes
Have the *review analyses* (Form 7s) addressed whether the proposal contributes to both merit review criteria?	Yes

Comments on NSF's merit review system:

It is clear that with the recent emphasis NSF has placed on review criterion 2 that investigators are making a better (and indeed, more diverse) effort to address this second criterion. There is a steady increase over the three years of evaluation in the percent of proposals addressing both criteria with the 2005 proposals showing 94% addressing the two criteria (table).

Reviews Addressing Review Criteria ***(from EIS)***

	FY 2003	FY 2004	FY 2005
# of Reviews	2,015	1,906	1,685
% Addressing Both Criteria	89%	92%	94%

AToL: The exciting impact of this focus on review criterion 2 is the diversity and extensiveness of the broader impacts being proposed. Many proposals incorporate undergraduate mentored research experience as part of their efforts and many focus on incorporating persons from underrepresented groups in their research efforts. Additionally, most proposals would disseminate results via new web portals and through the development of museum exhibits. There were proposals funded that had concerns relative to criterion 2 (e.g., Martindale et al. EF-0531558). In these cases, the proposal developed "standard" broader impacts of training graduate students and postdocs, but failed to go beyond the standard activities. Thus it appears that the AToL program may place less emphasis on review criterion 2 than on review criterion 1 (at least in this one case).

Bio-Math, Research: All reviews, analyses, and panel summaries examined did address both criteria. In some cases, the proposals themselves did not address the broader impacts clearly, but the reviewers described what they felt were very clear broader impacts.

Bio-Math, UBM: All reviews, analyses, and panel summaries examined did address both criteria. Because these were proposals for educational activities, the proposals likewise addressed both criteria clearly.

FIBR: Individual reviews almost always address both review criteria. However, broader impacts are consistently relegated to a few sentences (sometimes just one) whereas intellectual merit typically consists of several paragraphs. Moreover, many reviewers confuse broader impacts, as do PIs, with intellectual merit impacts. So, statements about broader impacts often talk about science, instead of considering such

components as teaching, underrepresented groups, infrastructure dissemination mechanisms, or benefits to society.

Panel summaries generally display the same skew as that noted above for individual reviews – broader impacts receive little discussion and typically only 1-2 sentences. Curiously, the review analyses often contain a more substantial discussion of broader impacts, but this was not translated into the panel summaries.

RCN: This is a program where broader impacts are especially appropriate and central to the overall success of the program.

Microbial Genome Sequencing: The merit review criteria were appropriately applied in evaluation of the proposals. The reviewer community consistently mentioned both review criteria in their initial comments as well as in the panel summaries.

Recommendations:

AToL: Continue the emphasis on review criterion 2 and encourage investigators to develop ideas that go beyond the standard efforts associated with university professors (mentoring students and postdocs) and museum curators (developing exhibits). The diversity of broader impact activities across the funded (and unfunded) AToL projects is impressive and should be showcased by NSF. For example, at the all PI meeting for the AToL projects, NSF might consider a special session on the outreach activities and invite experts in science education, etc.

FIBR: It is essential that panel summaries discuss broader impacts at a reasonable length. If only one or two sentences are included, it sends a message to PIs that they too should give it scant consideration. Perhaps summaries could reflect fairly closely the more balanced analysis of both review criteria as seen on the Form 7s. Perhaps instructions should emphasize that discussions of broader impacts should touch on each of the five components of broader impacts: teaching, underrepresented groups, infrastructure, dissemination, and societal benefits.

A.3 Questions concerning the selection of reviewers.

SELECTION OF REVIEWERS	YES , NO, DATA NOT AVAILABLE, or NOT APPLICABLE
Did the division make use of an adequate number of reviewers for a balanced review?	Yes
Did the division make use of reviewers having appropriate expertise and/or qualifications?	Yes
Did the division make appropriate use of reviewers to reflect balance among characteristics such as geography, type of institution, and underrepresented groups? **(Note: Data for underrepresented groups are not available).**	Yes

Did the division recognize and resolve conflicts of interest when appropriate?	Yes

Comments on selection of reviewers:

AToL: The review process for the AToL proposals is considered exemplary. To have 10 reviews for most projects, with a minimum of 8 for those surveyed, is really an amazing accomplishment. When you consider that these proposals are exceptionally interdisciplinary, inter-institutional, and international in scope and often include as part of the working group most of a particular taxonomic community, it is really amazing that NSF gets these proposals so well reviewed. The reviews come from a diversity of organismal, methodological, and ideological perspectives. They also come from a reasonably geographically broad spectrum with many international reviews.

Bio-Math: In both research and UBM proposals, there were at least 4 reviewers for each of the proposals examined, more often 5 or 6. The reviewers seemed to have appropriate expertise, and, for the UBM proposals, they came from a variety of institutional types and geographical areas. For the research proposals (admittedly a limited sample size), all reviewers were from large research universities. As far as we could tell, conflicts of interest were documented and reviewers appropriately removed from the process.

The FIBR program used reviewers with appropriate expertise and qualifications. Because choosing reviewers for proposals of the scope and magnitude of those in FIBR is not an easy task, we commend the members of FIBR's working group for their choice of reviewers. The reviewers were selected from a broad, and probably representative, geographical region. We are unable to assess whether the type of institutions are broadly represented as well. However, the number of females among reviewers seems low (19 females among 67 reviews that we sampled). The relative paucity of women among FIBR reviewers contrasts with the gender balance that seems to characterize some other programs in EF. As far as we can tell, the program uses the traditional NSF channels to recognize and resolve conflicts of interest. These channels appear to be very good at detecting and resolving conflicts of interest. However, they probably must be especially well-honed in EF initiatives that are often characterized by proposals and projects with multiple participants, broad interdisciplinary questions, and overlap among research groups.

RCN: Given the nature of these proposals, more than three reviews are recommended. (Note: Data for underrepresented groups are not available.) Difficult to assess diversity of reviewers based on aggregate data.

MicrGenSeq:The MicGenSeq had no difficulty in finding reviewers with appropriate scientific expertise. The geographic distribution of panelists may reflect the national funding patterns. Southern states appeared to be underrepresented in the cross section. Women were underrepresented, e.g. 5 of 18 in one set of reviewers. Underrepresented minority reviewers did not appear to be present in the reviewer set. No information was provided regarding inclusion of historically underrepresented U. S. scientists.

Recommendations:

AToL: We recommend that the AToL reviews continue in the excellent fashion that they currently use. NSF runs the risk of reviewer burnout with such high numbers of reviews from a relatively limited community, but they should continue as a goal to receive 8-10 reviews for each proposal.

FIBR: Reviewer selection is generally very good. Careful attention to the diversity of the reviewer pool needs to be emphasized.

A.4 Questions concerning the resulting portfolio of awards under review.

RESULTING PORTFOLIO OF AWARDS	APPROPRIATE, NOT APPROPRIATE, OR DATA NOT AVAILABLE
Overall quality of the research and/or education projects supported by the division.	Appropriate
Are awards appropriate in size and duration for the scope of the projects?	Yes
Does the division portfolio have an appropriate balance of: • High Risk Proposals?	Yes
Does the division portfolio have an appropriate balance of: • Multidisciplinary Proposals?	Yes
Does the division portfolio have an appropriate balance of: • Innovative Proposals?	Yes
Does the division portfolio have an appropriate balance of: • Funding for centers, groups and awards to individuals?	Yes
Does the division portfolio have an appropriate balance of: • Awards to new investigators?	Yes
Does the division portfolio have an appropriate balance of: • Geographical distribution of Principal Investigators?	Yes

Does the division portfolio have an appropriate balance of: • Institutional types?	Yes
Does the division portfolio have an appropriate balance of: • Projects that integrate research and education?	Yes
Does the division portfolio have an appropriate balance: • Across disciplines and subdisciplines of the activity and of emerging opportunities?	Yes
Does the division portfolio have appropriate participation of underrepresented groups?	Yes/No
Are the programs in the division relevant to national priorities, agency mission, relevant fields and other customer needs? Include citations of relevant external reports.	Yes

Comments on the quality of the projects or the balance of the portfolio:

AToL: The overall quality of the projects is exceptional and the balance of funded projects is also broad geographically and demographically. The AToL program, in particular, seems to allow for the inclusion of smaller institutions with taxonomic expertise into these large collaborative projects. For example, the funded McFadden project includes co-PIs from University of Louisiana Lafayette, Duke University, Pomona College (CA), Northern Illinois University, University of the Virgin Islands, Ohio State University, and the University of Kansas. From this one example, you can see both the geographic diversity, size diversity, and research emphasis diversity that is typical of the AToL projects.

Bio-Math: Quality not clear; no data were available on the outcomes of these proposals, in either research or UBM. Awards seem to be appropriate for the scope and duration of the proposals; a significant fraction of the UBM grants are 1 year supplements of limited scope.

Risk: Of the research grants we were able to examine, there were both high and lower risk proposals funded in reasonable proportion. None of the UBM grants were high risk, but as an education activity, this seems appropriate.

Multidisciplinary: By definition, all of these proposals are multi-disciplinary. The reviewers for the UBM proposals, particularly those that were not funded, appeared to put considerable emphasis on maintaining strict interdisciplinarity, so that programs needed to include elements designed to increase the mathematical competence of biology students as well as the biological competence of math students.

Innovation: Most of the proposals in Bio-Math included the development of innovative methodology for computations (research proposals), or new ways of integrating mathematics and biology in undergraduate education, with at least several innovative educational programs.

Centers/Groups/Individuals: Virtually all of the proposals in this category involve groups of investigators. The research grants are nearly all to collaborations involving several institutions; UBM proposals all are required to involve faculty from multiple departments within an institution.

New Investigators: There appears to be a reasonable balance of new investigators in both bio-math programs, but this is based on a small sample size.

Geographical distribution: Funded proposals in both bio-math programs come from a wide range of states.

Institutional types: All the bio-math research proposals that were funded (as well as most – or possibly all – of those that were submitted) came from large research universities. None appeared to be from either RUI institutions or historically minority-serving institutions. UBM projects were more balanced, with at least 2/8 each year coming from RUI institutions, although given that these are education grants, even this level seems lower than desirable. As far as we could tell, only 2 of the 24 UBM projects funded were to historically minority-serving institutions.

Balance across disciplines: The Bio-Math research projects are focused largely in two areas: biomedical problems (co-funded with NIH) and problems in ecology. There are clearly other areas that could reasonably be examined mathematically; they do not seem to be in these proposals, though they may be funded independently through the core programs. The UBM proposals that were funded nearly all seem to address a variety of biological programs; those that had a narrow focus were generally not funded.

Underrepresented groups: In the jackets we were able to view for the research proposals, there were no underrepresented minorities and no women PIs. Examining the PIs for all proposals funded in this program, it appears only 10% were women. In the UBM program, women were more prominent, accounting for over 30% of PIs and co-PIs, but underrepresented minorities were equally low.

Relevance: The bio-math programs provide for advances in both research and education at the interface of mathematics and biology, an area that is of considerable importance (see *Mathematics and 21st Century Biology,* National Academies Press, 2005). There are several societies (e.g. the Society of Mathematical Biology) devoted to this field, and conferences on the field and on education in this field also take place regularly (e.g., 39 conferences involving this interface that have taken place since 2001 are listed at http://dmoz.org/Science/Math/Applications/Mathematical_Biology/Events). The importance of this area for education is highlighted in a recent article in Science (*Introductory Science and Mathematics Education for 21st-Century Biologists*, W. Bialek and D. Botstein, Science 303: 788-790, as well as in an earlier report by the National Research Council (*Biology 2010: Transforming Undergraduate Education for Future Research Biologists,* National Academies Press, 2003). The UBM program is critical for this effort to improve the integration of education at the interface of biology and math.

The FIBR projects supported by EF are excellent. They are novel and integrative, and address the grand challenges of biology. They include a good balance of old questions (the origin of life, how do new species arise) and those that have emerged more recently but that are as challenging and fundamental (the genomics of ecological communities). It is the nature of FIBR proposals to be risky, multidisciplinary, and innovative. Perusal of reviews revealed that FIBR proposals satisfy these criteria. Five years seems adequate for FIBR projects. The FIBR portfolio includes a balance of disciplines and sub-disciplines: from genomics to community ecology, and from experimental research to theoretical and field studies.

In general, FIBR proposals fund groups of individuals. The 13 proposals that form the portfolio include 118 individuals as senior personnel. It does not fund large numbers of junior researchers as PIs. However, the projects include junior faculty as senior personnel. Perhaps more disturbingly, only 4 out of 17 PIs are women. This bias appears to reflect a bias in submission of FIBR that favors males. Only 23 out 143 FIBR submissions had females as PIs. Participation of under-represented groups in FIBR proposals is small as is the case in all EF proposals. This is ameliorated by the effort, clearly stated in many of the proposal's broader impact statements, that many PIs make to recruit under-represented groups among participating undergraduate and graduate students, and postdoctoral researchers.

FIBR projects are widely distributed geographically, but they are found predominantly in research universities. Only 2 out of 17 funded projects involved an institution other than a major research university. Typically the projects integrate education and research seamlessly. Their magnitude allows the interaction of undergraduates, graduate students, postdoctoral researchers, and junior and senior faculty. They are an ideal environment to foster learning through discovery.

The results of FIBR projects are relevant to national priorities and to NSF's mission. It is nearly impossible to have a single project that satisfies all these priorities but every funded FIBR project satisfies several of them. FIBR projects advance fundamental scientific discovery (numerous discoveries evidence their

success), they strengthen mathematics and engineering education by enabling students to learn as they discover (and discover as they learn), some of them are central to our ability to respond to global environmental issues.

RCN: If cyberinfrastructure needs are to be addressed in these awards, larger awards may be needed.
The merits of this program aren't necessarily tied to supporting "high risk" activities.
EF needs to promote this program in other areas of BIO other than in DEB.
EF should encourage broader participation of other BIO disciplines.
The RCN program fosters broad research collaborations resulting in community priority setting thereby optimizing limited research resources. This program provides a mechanism of breaking down disciplinary stovepipes. This program could be expanded well beyond BIO, and include interagency and additional international support.

MicGenSeq: The overall quality of the research and education projects is excellent. As many meritorious proposals were declined as were awarded. This is a standard problem in NSF/BIO funding. In any NSF/BIO budget climate it would be desirable to gain some sense of whether and to what degree is the MicGenSeq activity achieving initial goals. Program has managed this portfolio appropriately and provided examples of program achievements.

The period of 2001 – 2005 shows 108 awards made under the MicGenSeq as an interagency program activity. NSF collaborated with USDA to fund these projects and this represented a good model for interagency activity to advance scientific fields of mutual interest and importance.

The risk of awards varied. To a large degree the awarded grants were mostly straightforward sequencing projects with standard design to sequence genomes in previously cultured organisms. One of the pressing challenges remains how to obtain correct, complete genomic sequences for uncultured microbes.

The quality of research teams involved in the awarded grants is outstanding. The output, i.e. successful completion of genomic sequence on biologically important microorganisms that are not disease associated, has provided a critical information base to advance the basic understanding of biology and biological interactions at all scales.

The overall portfolio of awards does display a broad geographical representation of research-intensive universities. Whereas samples of individual panel reviews did appear to reflect geographical bias, the total portfolio content is more balanced. Though faculty or students from primarily undergraduate institutions, e.g. RUI institutions, may participate in some of these research and education groups, none appears to be a lead institution in a grant award.

The impact of these awards on racial and gender inclusion of U.S. citizens, particularly upon participation by historically underrepresented racial groups, is difficult to assess owing to the paucity of information reported to program. This needs a solution.

Recommendations:

AToL: Continue to encourage collaborative proposals with broad incorporation of a diversity of institutions and investigators. Place more emphasis on the incorporation of underrepresented groups in all levels of the proposals (PI, co-PI, postdocs, graduate students, undergraduates, K-12).

Bio-Math: It was notable that the types of institutions as well as the diversity of investigators who received research awards differed considerably from those who received UBM awards. Although it is possible that this is due to a failure to award bio-math research grants to a range of PIs in diverse institutions, it seems equally or more likely that it is due to a lack of applications in this area from those investigators and institutions. (It was not possible to determine this based on the information that we had available.) If this is the case, then it is particularly important to keep funding the UBM proposals, and to expand this initiative, putting particular emphasis on funding a broad array of investigators and institutions, as well as encouraging these programs to include a wide array of students. This may increase the chances that a larger group of investigators interested in and capable of working at this interface will be available to conduct this type of research in the future.

Overall, UBM has supported only 24 projects, and is expected to fund another 8 this year. If this program is to serve as a catalyst for change at additional institutions, it is clear that the existing projects need to be evaluated carefully, new ones funded, and the elements that contribute to successful programs need to be described and disseminated. To make this effort truly successful, it seems likely that a program to foster adaptation of successful programs at other institutions will be necessary.

RCN: This program could be expanded well beyond BIO, and include interagency and additional international support.

MicGenSeq: A workshop or other gathering for program guidance would be appropriate to consider the future strategy for directions of the MicGenSeq activity:

For example, where are the gaps in genomes in the growing Tree of Life with respect to the bacterial and archaeal organisms?

Utilize the results from surveys of prokaryotic diversity to gain a sense of what "out there" remains to be captured and for which whole genome sequences would be desirable or essential to fill in the branches of the ToL.

Consider incorporating a list of targets to construct goals for future sequencing projects. The sense of this is for the program to remain open to individual initiative but nudge the field to close identifiable gaps in needed information. This may include a focus on genomic sequence of uncultured organisms.

Devise an approach to learn from the awardees the extent of participation of underrepresented minorities and women who are U. S. citizens.

A.5 Management of the division under review.

Management of the program:

The management of EF was recently reorganized to provide real infrastructure to a formerly virtual Division. As part of this reorganization, the "Division" was reorganized into an Office within the Office of the Assistant Director for Biological Sciences. Associated with this reorganization, the BIO Senior Management team developed four criteria that might define EF projects, including 1) "Blue Sky" projects that address major unanswered questions, 2) activities that provide conceptual glue for BIO (i.e., cross-divisional activities) and beyond (i.e., across directorates), including NSF-wide priority areas and obligated activities, 3) value-added prospects by management in EF which might be management or scientific in nature, and 4) limited time activities. Based on these criteria, a number of activities were moved from EF and a number moved to EF. The COV agreed with the general flavor of the criteria including cross-cutting activities with a limited time frame and to think of EF as an incubator of potential new program areas that might eventually move into particular divisions (as it has served for programs like AToL and MicGenSeq). It is clear with this reorganization that office staff will be essential for managing the new portfolio of activities within EF. It also appears as though the mission of EF has changed slightly in that in addition to the charge to foster new activities that, if successful, would move into the core activities in BIO, the new EF office would also have more long-term activities (10 years) that would not be expected to move into core activities (RCN, centers, etc.). These activities provide an excellent opportunity for research communities to gather and generate novel cross-disciplinary ideas to be further developed as EF activities.

RCN: In the three years under review there seemed to be three somewhat different management models. The recommended structure would be "EF" office director, working group, central RCN panel, disciplinary panel, and ad hoc review. Rotators should be included on working group to maintain ties to the research community.

Responsiveness of the division to emerging research and education trends:

The Directorate for Biological Sciences established the Emerging Frontiers Subactivity in FY 2003 in order to support multidisciplinary research and networking activities arising from advances in disciplinary research, and to provide a mechanism by which new activities could be fostered and subsequently integrated into the core activities in BIO. These activities have been highly successful in generating data, establishing networks of research, promoting collaborations among disciplines, providing new and diverse educational opportunities, and providing exceptional return on the NSF investment. The AToL and MicGenSeq are two programs that are very successfully making the transition from EF to a divisional home. RCN will be a flagship program for EF.

Division planning and prioritization process (internal and external) that guided the development of the portfolio under review:

The Directorate for Biological Sciences established the Emerging Frontiers (EF) Virtual Division in FY 2003 in order to support multidisciplinary research and networking activities arising from advances in disciplinary research, and to provide a mechanism by which new activities could be fostered and subsequently integrated into the core activities in BIO. Initial activities included NSF-wide priority areas, Research Coordination Networks (a program that was a direct response to a community request), and new integrative activities such as Frontiers in Integrative Biological Research (FIBR). These programs and the BIO participation in the NSF wide Programs were established as a "virtual" Division, with no staff dedicated to EF and with shared management responsibilities in order to streamline financial management and to enhance communication within the Directorate and across the Foundation.

The five NSF-wide priority areas were: Biocomplexity in the Environment (BE), Information Technology Research (ITR), Nanoscale Science and Engineering (NSE), Mathematical Sciences (Math), and Human and Social Dynamics (HSD). Two Emerging Frontier Programs that were designed by the BIO directorate in consultation with the community are Frontiers in Integrative Biological Research (FIBR) and Research Coordination Networks (RCN).

The Portfolio is actually set by the scientific community as is the portfolio within the regular unsolicited proposal programs. The guidelines of these EF programs are so broad that they are not proscriptive and limiting. Review by disciplinary panels allows the evaluation by experts in the particular subset of biology and additional review where appropriate by a special panel or by program officers allows for geographical, gender, ethnicity and disciplinary diversity.

The NSF program managers do however play an important role in the final award decisions and it is recommended that these EF programs include rotators in the working groups and do not become the individual assignments for particular program officers for a long period of time. This will help to ensure new ideas and areas are given full consideration.

The cross – BIO working group management approach is crucial to provide the intellectual coverage required for these programs. The members of the working groups help to select panel members and ad hoc reviewers, and contribute to the decision-making process through post-panel meetings and debriefings. Each member of the working groups selects a subset of proposals for which that member retains primary responsibility throughout the review process. The working group chair is responsible for the day-to-day operations of the program including responding to inquiries by PIs, etc. This team-based approach has been highly successful. With the addition of an administrator and staff in the front office guiding the EF portfolio, additional responsiveness to the scientific community should be provided.

Broad participation by all of the BIO program directors is important in two respects. Firstly, they provide the intellectual depth and breadth necessary to cover the scientific range represented among proposals. Secondly, their acceptance of these interdisciplinary programs and their relationships to their own programs is crucial to the long-term success of emerging frontier programs.

As NSF-wide and BIO-wide new priority areas are set, then this Office will be the place to locate these programs to ensure BIO-wide participation of internal and external communities**.**

Discuss any concerns identified that are relevant to the management of the division:

The management of FIBR (and other programs) demands an unusual amount of collaboration among members of the working group. These individuals participate fully in the selection of ad-hoc reviewers and panel participants. They also rotate in the responsibility of chairing the panel. In addition to members of the working group, all BIO program directors participate in various aspects of FIBR. The broad inclusive

governance of FIBR guarantees the appropriate range of expertise needed to evaluate FIBR proposals and to foster the success of FIBR projects. An added benefit of the required broad participatory nature of FIBR is that this initiative acts as a cohesive force within BIO.

Recommendations:

The one shortcoming of a program like EF is that there may not be clear information about assessment available in one place (for one program manager) so that ongoing quality management can be assured. This issue should be addressed in future reorganizations.

The Agency needs to ensure that panelists are well informed of the program's goals and objectives before they prepare their reviews. It should then become rare that the working group's recommendations would appear to be at odds with the panelist scores.

PART B. RESULTS : OUTPUTS AND OUTCOMES OF NSF INVESTMENTS

B. Please provide comments on the activity as it relates to NSF's Strategic Outcome Goals. Provide examples of outcomes (nuggets) as appropriate. Examples should reference the NSF award number, the Principal Investigator(s) names, and their institutions.

B.1 OUTCOME GOAL for PEOPLE: Developing "a diverse, competitive and globally engaged workforce of scientists, engineers, technologists and well-prepared citizens."

Comments:

Several 'nuggets' illustrate the diverse, competitive and globally engaged workforce that EF research is developing.

0328363 Award Title: FIBR: Integrative Studies of Wolbachia-Eukaryotic Interactions; Genomes to Communities and Back
PI Name: John Werren

The Bay Paul Center hosted a three-day enhancement workshop in March, 2005 for 24 high school teachers, including several from Cape Cod. Using Wolbachia, a parasitic bacteria that live within insects as a model, workshop participants learned how microorganisms and their hosts interact. The workshop was designed to provide teaching tools and bring new life to science classes for high school teachers and undergraduate lecturers in the biological sciences. Lesson plans emphasized activities that can be used easily and inexpensively in the classroom to teach basic biological principles and covered insect collection and biodiversity, the bacteria that live within insects, DNA extraction, and simple molecular biology and evolutionary analysis skills. Workshop presentations and lesson plans are available for teachers to download at http://research.amnh.org/FIBR/workshops.html. Online access to these materials will allow the workshop to reach a much broader audience than just the teachers who attended.

0129928 Award Title: Institute for Neuromorphic Engineering (INE)
PI Name: Avis Cohen

This Research Coordination Network, in the form of an International Institute "without walls," is dedicated to the advancement of research and education in Neuromorphic engineering. Neuromorphic engineering is a young discipline in Bioengineering that is based on the design and fabrication of artificial neural systems, whose physical architecture and design principles are based on those of the biological nervous systems. The Institute for Neuromorphic Engineering (INE) aims to 1) foster the continuation and completion of specific collaborative interactions designated at the annual Workshop; 2) organize smaller and highly focused meetings throughout the year to allow the exchange of ideas and discussion on designated topics, as well as to hold a mid-winter meeting to discuss and evaluate the progress of the INE; and 3) organize and expand the education activities beyond the confines of the Workshop to other participating institutions. The outcome of this work is increased interaction between neurobiologists, computational scientists, and theoretical modelers, to better understand the mechanisms of neural activity underlying brain functions.

0425749 Award Title: FIBR: A Systems Approach to Study Redox Regulation of Functions of Photosynthetic Organisms
PI Name: Himadri Pakrasi
Institution Name: Washington University
Students participated in an eight-week course in systems biology concepts and methods, while working in a systems biology laboratory. They attended a "Frontiers in Integrative Biological Research" (FIBR) workshop, prior to the course and research experience. The FIBR workshop was led by Himadri Pakrasi, Ph.D., professor of biology in Arts & Sciences, and FIBR collaborators Rajeev Aurora, Ph.D., of Saint Louis University; Kenneth

D. Belanger, Ph.D., professor of biology at Colgate University; Bijoy Ghosh, Ph.D., WUSTL professor of electrical and systems engineering; and Ralph S. Quatrano, Ph.D., the Spencer T. Olin Professor and chair of the WUSTL Department of Biology. This 8-week summer program brings together students from different disciplines to learn to cross disciplinary boundaries and to acquire new skills and expertise.

0243867 Award Title: Ecosystem Function in Heterogeneous Landscapes: The Tenth Cary Conference, April 28-May 2, 2003
PI Name: Gary Lovett
Research Coordination Network award supports the Northeastern Ecosystem Research Cooperative (NERC), a grass-roots scientific organization of ecosystem researchers in the northeastern U.S. and eastern Canada. With NSF support the group will expand the disciplines represented and the breadth of the scientific community it serves, stimulating interactions between existing task groups, and initiating an outreach program that will help disseminate scientific information to the public and policy makers. Their goal is to have the NERC reach its full potential as a unique organization dedicated to synthesizing site-specific information from throughout the region and actively communicating that knowledge.

B.2 OUTCOME GOAL for IDEAS: Enabling "discovery across the frontier of science and engineering, connected to learning, innovation, and service to society."

Comments:
'Nuggets' provide information about the nature of discovery provided by EF research that reaches "across the frontier of science and engineering, connected to learning, innovation, and service to society."

0228675 PI Name: Shannon Hackett
0228617 PI Name: William Moore
0228688 PI Name: Frederick Sheldon
ATOL: COLLABORATIVE RESEARCH Early Bird: A Collaborative Project to Resolve the Deep Nodes of Avian Phylogeny
The Archosauria is a large group that includes living birds and crocodilians in addition to a number of extinct animals such as dinosaurs. Many fundamental questions about the evolution of one of the major branches of vertebrate life may be answered. These include, but are not limited to: How did modern birds originate? How and why did flight evolve in birds and pterosaurs? How do organisms transform from a terrestrial to an aquatic lifestyle? What characteristics explain extinction and survival across the Cretaceous-Tertiary boundary? The large size of the database will advance systematics by providing a large matrix for exploring questions about missing data, molecular versus morphological data, and many other issues.

0090227 RCN: Beyond "Deep Green": Toward an Integration of Plant Phylogenetics and Plant Genomics
PI Name: Brent Mishler
Deep Gene, is bringing together scientists from various disciplines to explore how plant phylogenetic comparisons (relationships between plants) can be used to better understand plant genomes and their functions and how genomics can be used to construct better phylogenetic trees showing relationships between plant species.

0425878 FIBR: Neuromechanical Systems Biology
PI Name: Robert Full
Student Crissy Huffard recognized that her observations of walking octopi were important to a question in another scientific context: how exactly do these animals move? This question connected her to Full, whose work emphasizes that the material properties of moving appendages strongly influence the mechanics of movement. One of the goals of the FIBR Program is to support the training of students who are fearless in working across disciplinary boundaries. Students like Crissy Huffard, who are willing and able to work across scientific boundaries, are a powerful force for removing pre-conceived disciplinary barriers.

Full and Huffard have worked together to identify a system that will allow determination of whether control principles of soft-bodied movement are more complex than that for jointed appendages. Conclusions of the work will be extended to robotic theory, allowing the team to explore solutions for a robot's movement across varied or rough terrain.

0509923 Microbial Genome Sequencing: The Cenarchaeum Symbiosum Genome Project: Genome Sequence from a Psychrophilic Archaeon, the Ocean's Single-most Abundant Microbes
PI Name: Edward DeLong
Planktonic microbes are microscopic organisms that reside in the ocean. While helping to maintain environmental balance, these microbes also drive the Earth's cycles of carbon, nitrogen, oxygen and sulfur. With support from an NSF grant, an interdisciplinary team of research scientists headed by Dr. Edward DeLong at MIT, sequenced and compared the genomes of planktonic microbes living at varying depths in the Pacific Ocean. Sequencing 64 million base pairs of DNA from microbes and viruses, Dr. DeLong and his group discovered thousands of novel genes from both new and previously known microbes. Along with frequent gene exchange between organisms, their study also revealed varying genetic compositions at different depths. They discovered that microbes near the ocean's surface have more genes devoted to the uptake of iron while the genomes of microbes that live deep within the ocean possessed genes with the ability to move from one part of the genome to another or so-called "jumping genes". The findings of their research, which were published in Science, will allow for a clearer understanding of how the genomes of microbial communities affect their interaction with the environment.

B.3 <u>OUTCOME GOAL for TOOLS:</u> Providing "broadly accessible, state-of-the-art S&E facilities, tools and other infrastructure that enable discovery, learning and innovation."

Comments:

Many of the EF awards have tool development as a central focus of their activities and have indeed produced phenomenal results. These include tools in the broad categories of informatics, molecular biology, and education. We provide some examples of these from the various programs below.

Informatics
0121682
PI Name: Tandy Warnow
Institution Name: University of Texas at Austin
The PI and team produced much faster software for tree-set visualization and clustering. Such tools are useful for understanding the large sets of optimal or near-optimal trees that are produced by the optimization programs for computing phylogenies given sequence or character data. They can also be used to show the behavior of the tree-search algorithms within the space of possible trees, giving insight into different search strategies and possibly allowing the user to monitor the progress of frequently long search. The tools for the visualization and comparison of very large trees will be essential as larger and larger phylogenies are computed. The advancements made here will facilitate Assembling the Tree of Life and other large phylogenetic endeavors.

Molecular Biology
0135210
PI Name: Mary Ann Moran
Institution Name: University of Georgia Research Foundation Inc
This study determined the complete genome sequence of the bacterium, *Silicibacter pomeroyi* DSS-3. Thee sequence and its analysis appeared in the December 16, 2004 issue of *Nature*. This bacterium is significant because it is a member of an important group of marine microbes (the roseobacters) that influence gas exchange between the ocean and the atmosphere. An unexpected finding from the genomic analysis was evidence of lithohetrotrophy, in which inorganic compounds (i.e. carbon monoxide and sulphide) are used to generate energy. Lithohetrotrophy allows *S. pomeroyi* cells to use organic compounds more efficiently for biosynthetic processes in low-nutrient ocean environments. With the complete genome sequence in hand, the investigators are now able to further develop molecular tools to study the microbiology and ecology of bacterially mediated organic sulfur transformations in the ocean.

Education

0328363
PI Name: John Werren
Institution Name: University of Rochester
The Bay Paul Center hosted a three-day enhancement workshop in March, 2005 for 24 high school teachers, including several from Cape Cod. Using Wolbachia, a parasitic bacteria that live within insects as a model, workshop participants learned how microorganisms and their hosts interact. The workshop was designed to provide teaching tools and bring new life to science classes for high school teachers and undergraduate lecturers in the biological sciences. This was a hands-on workshop allowing 24 high school teachers from throughout New England to work together in developing new laboratory teaching modules. Workshop presentations and lesson plans are available for teachers to download at http://research.amnh.org/FIBR/workshops.html.

B.4 OUTCOME GOAL for ORGANIZATIONAL EXCELLENCE: Providing "an agile, innovative organization that fulfills its mission through leadership in state-of-the-art business practices."

Comments:

Interestingly, the outcome goal for organizational excellence comes from both the funded projects within the EF Division as well as from EF itself. The management of many of these projects is difficult. Within NSF it requires coordinating within working groups, across multiple program directors, using ad-hoc highly interdisciplinary panels to evaluate complex multidisciplinary projects. Once a project is funded, the workgroup and responsible program directors aid PIs in the management of diverse and complicated consortia of researchers and educators. The flexible and nimble management adopted by NSF to handle EF proposals and projects is exemplary and should probably be emulated by organizations that must deal with complex multidisciplinary groups or that aim to solve important problems and that tackle ambitious multi-faceted problems. Indeed, universities that hope to foster interdisciplinary research programs should use this organizational scheme as a model for success. This approach has fostered buy-in and ownership across divisions with a strong (and well deserved and justified) sense of accomplishment on behalf of the program directors.

Within particular programs, the awards have provided a model for the scientific community to cross disciplinary boundaries and to form productive collaborations that allow novel insights into biological systems. Such organization allows for synergies that bring large returns relative to the dollars invested in the programs when compared with standard grant applications. Some of the organizational products of RCNs, for example, include :

- Developing and integrating databases
- Promoting community effectiveness
- Promoting young investigators
- Improving science scope
- Encouraging Integrative training
- Creating new disciplines and new technologies
- Sharing research resources
- Developing educational materials
- Developing new research tools for common use
- Fostering Interdisciplinary understanding
- Enhancing networking skills
- Increasing science availability
- Standardizing technology and analysis.

Despite the wide range of scientific fields, community structures, and specific activities among the programs and projects, the participants identified a common set of mechanisms essential to the success of their interdisciplinary endeavors. These common mechanisms included:

- Developing trust
- Assembling core groups
- Providing for recognition/ acknowledgement
- Ensuring specific focus from diverse disciplines
- Fostering openness
- Exploiting unique opportunities
- Expanding comparative science
- Looking for opportunities to accelerate science
- Identifying and understanding barriers between communities.

In addition to the general organizational lessons learned from both NSF and the programs themselves and associated projects as a whole, below we provide some examples of particular projects that provide good examples of innovative organization.

0502081
PI Name: Brent Mishler
Institution Name: University of California-Berkeley
One of the most profound ideas to emerge from biological research over the last decade is the realization that all life, from the smallest microorganism to the largest vertebrate, is connected through evolutionary relationships to form a single, vast evolutionary tree, the *Tree of Life*. A meeting of all investigators on AToL grants was held November 2004, at NSF in Washington, DC. The 22 funded projects as of then reported that they were making fast progress and were producing data on an unimaginable scale. The interactions of the researchers at this workshop demonstrated that the field of biological systematics is changing: the field has been transformed by these large groups of collaborating workers pooling their efforts to advance toward a common goal. It is clear that a "big science" approach is necessary to answer really important questions such as reconstructing the enormous and complex tree of life. Collaborative research is a fundamental part of the Assembling the Tree of Life program, and this workshop of all investigators demonstrated the value of coming together to work on one scientific goal.

0233854
PI Name: Ruth Stark
Institution Name: CUNY College of Staten Island
This project has fostered communication of ideas and allowed exposure to off-campus equipment facilities for six research groups at the City University of New York (CUNY), the New York Structural Biology Center, Columbia University, and New York University. The networking was accomplished through an ongoing seminar series held at participating institutions across New York City; an annual symposium held alternately at the CUNY Graduate Center and at the New York Structural Biology Center; an annual hands-on workshop rotating among different laboratories of the core participants; a communications system for teleconferencing and video conferencing; and an interactive website to announce these activities. These activities facilitate both junior and well-established investigators to exchange ideas and results, form collaborations, and advance the field of solid-state NMR. In addition, the seminars and website reach researchers who would not otherwise have ready access to state-of-the-art NMR methods. The Research Coordination Network includes a significant population of minority students, who comprise about 60% of CUNY's student population.

0129792
PI Name: William Michener
Institution Name: University of New Mexico
A BIO-sponsored Research Coordination Network, the "Resource Discovery Initiative for Field Stations," is working to accelerate the integration and standardization of information technologies throughout biological field stations. These field stations serve not only as research facilities for investigating a wide range of environmental challenges, but also as a training grounds for young scientists. The Network is working to standardize vocabulary across field stations by developing a Thesaurus for Field Biology. Additionally, the Network is developing a Data Registry for field stations that would make important environmental data

accessible to other scientists as well as policymakers, educators, and the general public. This Network is working to implement new sensing technologies and databases, making data from field stations across the continent easily accessible and useful to the community.

PART C. OTHER TOPICS

C.1 Division areas in need of improvement or gaps (if any) within division areas.

Before this question can be answered, there must be a clear understanding of what the Directorate hopes to accomplish with this virtual program. While the COV understands that EF has been serving multiple needs as reflected in its current scope of activities, it has devolved into a collection of important programs that have little discernable rationale for inclusion in something called Emerging Frontiers. As proposed, the future EF will provide a home for programs that support activities that are (based on new criteria): high risk but with high intellectual payoff (blue sky), conceptually cross-cutting (glue), in need of value-added EF management, and time limited. In addition EF will take on a variety of large centers to ensure and foster good management practices.

An important function that the COV was excited to discern was that of an incubator. For example, FIBR and RCN are unique interdisciplinary activities that benefit from placement in EF. The success of FIBR grants in achieving the program's stated objectives is uncertain and, therefore, these programs must be seen as an incubator. Other programs that transcend traditional disciplinary boundaries are also appropriate for inclusion in EF. Inclusion of the centers is also justified, but for different reasons. With the centers, there are managerial imperatives ranging from managing the funds to lessons learned in center management/oversight.

Because of the overlapping nature of EF programs, there are no obvious gaps – EF has been a collection site for a range of programs that have needed a place for reasons of either their overarching and interdisciplinary nature, which requires input from more than one division (or even more than one directorate within NSF, or beyond) or because of the ways in which they have been initiated and funded. Even with the new determination of criteria by which programs become housed in EF, there is not a range of content that should be covered by EF. Instead, what will be needed is a continual examination of areas in which interdisciplinary programs would be appropriate and should be added to the range of programs supported by BIO. If this "division"/office is to serve effectively as an incubator for new programs and ideas, those ideas must be consciously considered on a regular basis, so that "gaps" do not develop.

It is not clear that establishing an entirely common set of criteria for EF activities is necessary; there are many good reasons why the existence of an EF-like office is highly beneficial to both BIO as a directorate and to science with a somewhat heterogeneous portfolio. (For example, high risk science might not be supported by risk adverse panels; there are managerial imperatives; it will provide an incubator for new programs; it may overcome divisional/disciplinary silos; etc.) **We recommend a five year review cycle to determine what programs should remain in EF, what programs should be terminated, and what programs should graduate to one of the existing BIO divisions. For each program, a clear rationale should be developed explaining (to the community broadly) why a given program is part of the EF portfolio.**

The organization of the new division for management of the changing portfolios is clearly still in flux. This was of concern to the COV and discussion with DD did not clarify these concerns. For example, although real FTEs are being added to this virtual division and future office, it is not clear how these FTEs will impact program officer workloads. The operation of this office will still depend upon the actions of program officers in the divisions.

It is our impression that the reorganization of this office, under the direction of a single person, together with the new criteria (appropriately applied) to determine what will be included in the office, will improve the management of the program as a whole, while still allowing for the appropriate expertise in reviewing and managing individual components of the program by program officers based in all the other divisions. This is the ideal time to re-think the management model for EF. The cycling of personnel through the director job needs to be timed correctly (is one year adequate time to make progress?). The rewards to the staff (titles and salary) should reflect the importance that the Directorate attaches to EF type activities.

It is also important that the nature and purpose of this office be clarified to the community, and that the name of the office portray more clearly what it actually does. A clear statement of the purpose of this office will be very helpful to all stakeholders. In particular, the office must draft a new mission statement. This mission statement must encapsulate the office's goals and mission and clearly state its dual purpose as BOTH an incubator AND as a coordinating center for BIO's centers.

There is a general issue with the name "EF." Unfortunately, the current name, Emerging Frontiers, does not reflect its current set of constituent parts and alienates many since it implies that in BIO – EF is where the frontiers are addressed. In fact, each division supports work at the scientific frontiers. The panel recommends a name more in keeping with the expectations for the office. The name should reflect the fact that the office supports programs that are interdisciplinary, trans-foundation/agency, or have an uncertain future (i.e., a program incubator). Suggestions include Office of Integrative Activities and Programs (OIA / P), Office of Interdisciplinary Activities and Program Development (OIAPD), Office of Adaptive Programs (OAP), Office of Multidisciplinary and Adaptive Programming (OMAP), Office of Multidisciplinary and Adaptive Initiatives (OMAI), BIO Integration Office for Transdisciplinary Activities (BIOTA).

Recommendations:

1. A five year review cycle should be implemented to determine what programs should remain in EF, what programs should be terminated, and what programs should move to one of the existing BIO divisions.

2. The office must draft a new mission statement. It should encapsulate the office's goals and mission and clearly state its dual purpose as BOTH an incubator AND as a coordinating center for BIO's centers.

3. The panel recommends a name more in keeping with the expectations for the office.

4. We strongly recommend that the new division strongly emphasize assessment and that the assessment plans highlight workforce issues prominently.

C.2 Please provide comments as appropriate on the division's performance in meeting division-specific goals and objectives that are not covered by the above questions.

Current Mission Statement: "The Emerging Frontiers (EF) Division is an incubator for 21st Century Biology. EF supports multidisciplinary research opportunities and networking activities that arise from advances in disciplinary research. By encouraging synergy between disciplines, EF provides a mechanism by which new initiatives will be fostered and subsequently integrated into core programs."

What is the overall success of EF in light of its goals and objectives? To answer this question, we must first clarify what the goals of the division are. It is our impression that EF's mission statement and recent identification of criteria for inclusion in EF goes a long way towards identifying this office's objectives and goals. In C.1 we recommend a new mission statement. **Here we recommend that EF follows its new mission statement with a more detailed account of its objectives and goals. For operational reasons we will assume that EF has four major objectives. We believe that these should be EF's functions in its novel reincarnation:**

1) **EF should serve as an incubator for new and interesting areas that are likely to cut across biology and that are sometimes (albeit not exclusively) interdisciplinary – this will allow them to be funded and looked after for a number of years by program officers from multiple disciplines. They may then move to another division, potentially be renewed in EF, or be eliminated if they have served their purpose and are no longer in need of support.**
2) **EF should serve as a longer-term home for programs that are interdisciplinary and cut across all of the divisions, such as the RCN program.**

3) **EF should manage a series of programs such as the Centers, that may be more disciplinary in content, but differ from the usual programs and can benefit from interacting with one another in terms of management and ways of structuring activities that are inherent to that type of program.**
4) **Finally, we believe that EF should serve as an incubator for novel mechanisms of collaborative management modes, initiative and grant assessment, and dissemination of results. Adopting an adaptive approach to these themes should not be take place exclusively within EF, but the incubator nature of this office appears to suit it well as an arena for experimentation.**

Given these three purposes, how well has EF performed? Two initiatives (AToL and MicSeq) have been very successful and ripened enough to be transferred from their incubation chamber in EF to DEB and MCB, respectively. **RCN is a successful initiative. We recommend RCN as one of the division's, and perhaps the directorate's, flagship programs.** It is too early to evaluate the success of FIBR. The initiative appears to be successful but its performance relative to that of programs that rely on standard, "individual investigator" initiatives, remains to be assessed. Finally, the BIO Math initiative is hard to evaluate. The program included two components: research and education. The research component of BioMath has been transferred to other divisions -appropriately. The success of the educational component remains to be assessed. **Given the success of the RCN initiative, we propose a similar one for education on the biological sciences. The Science Education Coordination Networks (SECN). The objectives of this proposal would parallel those of the RCNs.** The goal of this program would be to encourage and foster interactions among scientists and educators to create new research directions or advance how a field is taught at the undergraduate levels. Innovative ideas for implementing novel networking strategies are especially encouraged. Groups of investigators and educators will be supported to communicate and coordinate their educational activities across disciplinary, organizational, institutional, and geographical boundaries. The proposed networking activities should have a theme as a focus of its collaboration. The focus could be on an area of biology (e.g. genetics, cell biology, ecology, etc.) or on interdisciplinary themes (mathematics in biology, earth as a living system,…, etc.).

Conducting EF's COV assessment made us realize how difficult it is to evaluate the success of its programs. The assessment difficulties are two-fold: First, EF includes programs that have particular and sometimes divergent objectives. Second, NSF does not have efficient mechanisms to evaluate the performance of programs. **Our recommendation to begin solving this problem is two-fold. First, new initiatives recommended for incubation and nurturing in EF must have well defined objectives and goals at their onset and a mechanisms that permits assessment of those. Second, we recommend that EF begins experimenting with quantitative assessments of broad impacts. Many of the elements of these broad impacts, including work force development (gender balance, inclusion of minorities, and RUI participants), education (courses developed, number of participants), and outreach (website and exhibit development), can be evaluated quantitatively with relative ease.**

C.3 Please identify agency-wide issues that should be addressed by NSF to help improve the division's performance.

The COV was pleased with the enthusiasm expressed by program directors and rotators for the activities within EF. We attribute this enthusiasm to the inclusive policies that guide the evaluation and implementation of EF initiatives. The role of working groups in the success of EF is absolutely crucial, as is the establishment (or continuation) of frequent communication between the EF director and program directors and staff. This is especially important now that EF will have staff and its responsibilities will become more centralized. Although the interaction between EF's staff is exemplary, we noted a paucity of rotating staff within the working groups. Rotating staff can bring new ideas and enthusiasm to the working groups. We believe that the inclusive management of EF with its emphasis on inclusion, distributed administration, and communication can provide a model for the administration of 21st science which tends to be multidisciplinary and collaborative. **Thus the COV recommends a mixture of rotators and permanent staff in the EF initiatives.**

Some of the programs in EF, notably Bio-Math, are cross-directorate, and so benefit from communication and cooperation between these directorates (including not only BIO and Math, but also DUE). The UBM program has not been funded for long enough to determine the extent of its impact, but if the impressions of the

program officers involved in the Bio-Math working group are correct, this is likely to be a highly effective program, and therefore one that needs to be maintained, and expanded, so that the lessons learned can be spread to other institutions to enable broad changes in the education of students in both biology and mathematics. Indeed, many of the activities in EF can and should serve as models for interdisciplinary (cross-directorate) organization and management (see B.4). BIO needs to assess carefully whether there is a need for this program to continue even though the funding that originally supported it may be ending. **The COV recommends, then, that the UBM program be maintained and expanded and that appropriate objectives coupled with ongoing assessment be integral parts of this continuation. The COV further recommends that for these cross-directorate activities can be "rewarded" (leveraged) with existing "Director's Reserve" funds – especially where the participating programs have relatively small budgets to start with. However, the COV would not recommend any additional taxation of core programs to create or augment such a reserve.**

Perhaps the biggest issue that cuts across NSF is the need for a mechanism for analysis and assessment of outcomes from all programs. Having data (in annual reports and final reports) available in a way that is easy to access in an automated way, so that ongoing assessment is possible and reasonably easy, is extremely important, particularly for programs such as those in EF that need to be assessed to determine their future. This is especially important in assessing the results of these programs in terms of the broader impacts. Indeed, it would be a great advance if NSF developed a mechanism where data were collected from applicants and successful PIs (annually) so that information about gender, ethnicity, institution type, geographic region, etc. could more easily be collected any time a COV visits. We received many clear statements about how members of underrepresented groups were doing from program officers, based on impressions and anecdotes, but very little in terms of statistics and overall summaries. **The COV recommends that NSF develop an annual report format that allows for the retrieval of data related to research AND broader impacts in an automated fashion.** The COV identified great inconsistencies in the expectations for broader impact statements in grant proposals (from a few words to a serious project) both on behalf of the program officers and the reviewers and panels. The US faces a crisis in the education and training of its citizens for the scientific workforce. Until NSF elevates the broader impacts to a primary agenda item and goal that is part of the fabric of the strategic goals and mission of the NSF, this goal will remain unmet and unattainable. EF could have significant impact as an assemblage of relatively large-dollar projects. Expectations must be raised foundation-wide. **The COV recommends that EF set the bar for expectations in the area of broader impacts across not only the directorate but across the foundation.**

The final concern of the COV relative to agency-wide issues is the commitment to the GRPA standards especially relative to the expected time line for review return to investigators. The EF programs have done a great job in this area, meeting the 70% within 6 month goal. However, it is conceivable, with the addition of more activities under EF, the added administrative burden of existing EF programs moving to divisions and the complexity of much of the EF activities, that meeting the GRPA performance goals may become administratively challenging. **Thus the COV recommends that the management team keep a close eye on the administrative burden of the EF and EF-associated activities on the program officers and develop an FTE distribution plan to assure a reasonable distribution of this burden.**

C.4 Please provide comments on any other issues the COV feels are relevant.

When the EF programs are reviewed in the future, we urge that all programs be reviewed at the same time so a coherent picture of EF can be constructed. This may be a logistical challenge given that there probably will be more programs within EF in the future (about 14). However, even if this requires a larger committee or even subcommittees it should be worthwhile.

The AToL has an interesting, but unevenly applied practice for stimulating collaboration amongst applicants and PIs. "If two or more proposals with overlapping goals and scope remain in consideration for funding after initial merit review, the PIs of those proposals are asked to collaborate and to submit a coordinating plan prior to final funding decisions." This is probably an approach that cannot be adopted in many core program areas; however, it may be a valuable way to stimulate broader participation – both intellectually and in terms of people power – within the often collaborative mode of EF programs. Perhaps wider and more uniform adoption of this approach should be explored. This might be a particularly important mechanism to broaden

research networks to include a greater variety of institutions such as primarily minority serving and undergraduate institutions.

Recommendations:

- **Conduct comprehensive "EF" COV reviews to better enable the Committee to develop a coherent picture of the EF portfolio and address more fully Division-wide issues.**

- **Explore the possibility of expanding the AToL practice of fostering collaboration amongst PIs submitting proposals with overlapping goals and scope.**

C.5 NSF would appreciate your comments on how to improve the COV review process, format and report template.

Information Supplied Prior to the COV meeting

In general, accessing information before coming to NSF for the COV was not as easy as is desirable. Many of the documents required going to one document, copying URLs, pasting them into a browser and finding another document, so that individual members of the committee easily spent an hour or more just downloading and printing documents. Compiling them as a single file (or two to three files) would have made preparation more efficient.

Provision of a self-study document was extremely helpful in getting the COV committee started. In our particular case, it would have been especially helpful if there had been some breakdown of the data by each individual program – even if it was aggregate information for three fiscal years. (In fact, such aggregate information is probably more useful than breakdowns by fiscal year when looking at individual programs.) However, it is important to emphasize that the data in the self study were very clear and helpful.

The data summaries of BIO dollar investments and proposal numbers were very helpful. In cases where there is additional programmatic investment from outside BIO it is important to see some similar summary statistics. If proposals were on the books as funded by other parts of NSF, that data were not included and led to skewed and erroneous information. We imagine these might be difficult to obtain, but they would be strategically valuable for the Directorate and the COV.

The content of the self –study document could be improved. The history of the virtual division, perceived needs and directions, how programs were selected for inclusion, data disaggregated by program, and particular points of consensus and non-consensus would be informative, as would inclusion of the program's mission statement.

Information during Panel

The COV would have been more efficient if the very clear verbal description of this virtual division, including its history, purpose, recent changes and future, that was presented by Judy Verbeke on the second morning in response to questions (and confusions) at the end of the first day of the meeting had been presented on the first morning, before we heard from the other groups and examined jackets.

Having a very short review of each program by the involved program officers (working groups) would have been helpful at the start of each session. In some cases we had to spend a considerable amount of time getting to issues that were important to the Program Managers. In some cases, the data provided were refuted by the Program Managers as incomplete or not the most relevant data set. We also did not have an opportunity to ask other program officers their opinion of these programs.

The ability to access other jackets was limited. Giving the COV electronic access to all jackets in the program from the beginning of the meeting would have been very helpful. The selection of particular jackets to view was "random" selection. However with some of the smaller programs, this lead to very uninformative jackets (in one case all withdrawn proposals, in another case all awarded proposals and in a third a case only one award and five declinations). A quick review of these selections would have pointed this out and additional jackets could have been

added to make sure the sample was adequate for the COV review. A stratified sample would be a more effective mechanism.

It would be very helpful if there were a way for the panel to move from the e-jacket work space to a page where the COV document can be seen as it is assembled, and/or where files can be shared. On a regular panel, the computers are networked so that the panelists can share information readily rather than printing our hard copies or sending back and forth via home institution web sites as this COV had to do.

PART D. DIVISION LEVEL QUESTIONS

D.1 Please comment on actions taken by the Division in response to the last COV's recommendations.

N/A

Recommendations by Section

A. 1.

AToL: The review process for the AToL proposals is considered exceptional both in the quantity and quality of reviews. This is exceptionally helpful to investigators in further developing successful projects. There are no data on the timing of review return to investigators for this particular program, but given the annual (instead of biannual) deadline for this competition, the 6 month return time is less critical and the Division is certainly close to the goal of 70% return within 6 months across the programs evaluated. Thus the recommendation is to continue the exceptional review process for the AToL proposals.

Continued attention needs to be paid to providing enough critical discussion of strengths and weaknesses in panel summaries for the PI's benefit. In addition, broad impacts must be sufficiently emphasized.

RCN: Need to more effectively inform reviewers of the special review criteria within the merit and broader impact framework.

A. 2.

AToL: Continue the emphasis on review criterion 2 and encourage investigators to develop ideas that go beyond the standard efforts associated with university professors (mentoring students and postdocs) and museum curators (developing exhibits). The diversity of broader impact activities across the funded (and unfunded) AToL projects is impressive and should be showcased by NSF. For example, at the all PI meeting for the AToL projects, NSF might consider a special session on the outreach activities and invite experts in science education, etc.

FIBR**:** It is essential that panel summaries discuss broader impacts at a reasonable length. If only one or two sentences are included, it sends a message to PIs that they too should give it scant consideration. Perhaps summaries could reflect fairly closely the more balanced analysis of both review criteria as seen on the Form 7s. Perhaps instructions should emphasize that discussions of broader impacts should touch on each of the five components of broader impacts: teaching, underrepresented groups, infrastructure, dissemination, and societal benefits.

A. 3.

AToL: We recommend that the AToL reviews continue in the excellent fashion that they currently use. NSF runs the risk of reviewer burnout with such high numbers of reviews from a relatively limited community, but they should continue as a goal to receive 8-10 reviews for each proposal.
FIBR: Reviewer selection is generally very good. Careful attention to the diversity of the reviewer pool needs to be emphasized.

A. 4.

AToL: Continue to encourage collaborative proposals with broad incorporation of a diversity of institutions and investigators. Place more emphasis on the incorporation of underrepresented groups in all levels of the proposals (PI, co-PI, postdocs, graduate students, undergraduates, K-12).

Bio-Math: It was notable that the types of institutions as well as the diversity of investigators who received research awards differed considerably from those who received UBM awards. Although it is possible that this is due to a failure to award bio-math research grants to a range of PIs in diverse institutions, it seems equally or more likely that it is due to a lack of applications in this area from those investigators and institutions. (It was not possible to determine this based on the information that we had available.) If this is the case, then it is particularly important to keep funding the UBM proposals, and to expand this initiative, putting particular emphasis on funding a broad array of investigators and institutions, as well as encouraging these programs to include a wide array of students. This may increase the chances that a larger group of investigators interested in and capable of working at this interface will be available to conduct this type of research in the future.

Overall, UBM has supported only 24 projects, and is expected to fund another 8 this year. If this program is to serve as a catalyst for change at additional institutions, it is clear that the existing projects need to be evaluated carefully, new ones funded, and the elements that contribute to successful programs need to be described and disseminated. To make this effort truly successful, it seems likely that a program to foster adaptation of successful programs at other institutions will be necessary.

RCN: This program could be expanded well beyond BIO, and include interagency and additional international support.

MicGenSeq: A workshop or other gathering for program guidance would be appropriate to consider the future strategy for directions of the MicGenSeq activity.

For example, where are the gaps in genomes in the growing Tree of Life with respect to the bacterial and archaeal organisms?

Utilize the results from surveys of prokaryotic diversity to gain a sense of what "out there" remains to be captured and for which whole genome sequences would be desirable or essential to fill in the branches of the ToL.

Consider incorporating a list of targets to construct goals for future sequencing projects. The sense of this is for the program to remain open to individual initiative but nudge the field to close identifiable gaps in needed information. This may include a focus on genomic sequence of uncultured organisms.

Devise an approach to learn from the awardees the extent of participation of underrepresented minorities and women who are U. S. citizens.

A. 5.

1. The one shortcoming of a program like this is that there may not be clear information about assessment available in one place (for one program manager) so that ongoing quality management can be assured. This issue should be addressed in future reorganizations.

2. The Agency needs to ensure that panelists are well informed of the program's goals and objectives before they prepare their reviews. It should then become rare that the working group's recommendations would appear to be at odds with the panelist scores.

C. 1.

1. A five year review cycle should be implemented to determine what programs should remain in EF, what programs should be terminated, and what programs should move to one of the existing BIO divisions. For each program, a clear rationale should be developed explaining (to the community broadly) why a given program is part of the EF portfolio.

2. The office must draft a new mission statement. It should encapsulate the office's goals and mission and clearly state its dual purpose as BOTH an incubator AND as a coordinating center for BIO's centers.

3. The panel recommends a name more in keeping with the expectations for the office.

4. We strongly recommend that the new division strongly emphasize assessment and that the assessment plans highlight workforce issues prominently.

C. 2.

1. We recommend that EF follows its new mission statement with a more detailed account of its objectives and goals. For operational reasons we will assume that EF has four major objectives. We believe that these should be EF's functions in its novel reincarnation:

5) EF should serve as an incubator for new and interesting areas that are likely to cut across biology and that are sometimes (albeit not exclusively) interdisciplinary – this will allow them to be funded and looked after for a number of years by program officers from multiple disciplines. They may then move

to another division, potentially be renewed in EF, or be eliminated if they have served their purpose and are no longer in need of support.

6) EF should serve as a longer-term home for programs that are interdisciplinary and cut across all of the divisions, such as the RCN program.
7) EF should manage a series of programs such as the Centers, that may be more disciplinary in content, but differ from the usual programs and can benefit from interacting with one another in terms of management and ways of structuring activities that are inherent to that type of program.
8) Finally, we believe that EF should serve as an incubator for novel mechanisms of collaborative management modes, initiative and grant assessment, and dissemination of results. Adopting an adaptive approach to these themes should not be take place exclusively within EF, but the incubator nature of this office appears to suit it well as an arena for experimentation.

2. RCN is a successful initiative. We recommend RCN as one of the division's, and perhaps the directorate's, flagship programs.

3. Given the success of the RCN initiative, we propose a similar one for education on the biological sciences. The Science Education Coordination Networks (SECN). The objectives of this proposal would parallel those of the RCNs.

4. Our recommendation to begin to solve the problem of appropriate evaluation is two-fold. First, new initiatives recommended for incubation and nurturing in EF must have well defined objectives and goals at their onset and a mechanisms that permits assessment of those. Second, we recommend that EF begins experimenting with quantitative assessments of broad impacts. Many of the elements of these broad impacts, including work force development (gender balance, inclusion of minorities, and RUI participants), education (courses developed, number of participants), and outreach (website and exhibit development), can be evaluated quantitatively with relative ease.

C. 3.

1. The COV recommends a mixture of rotators and permanent staff in the EF initiatives.

2. The COV recommends that the UBM program be maintained and expanded and that appropriate objectives coupled with ongoing assessment be integral parts of this continuation. The COV further recommends that for these cross-directorate activities can be "rewarded" (leveraged) with existing "Director's Reserve" funds – especially where the participating programs have relatively small budgets to start with. However, the COV would not recommend any additional taxation of core programs to create or augment such a reserve.

3. The COV recommends that NSF develop an annual report format that allows for the retrieval of data related to research AND broader impacts in an automated fashion.

4. The COV recommends that EF set the bar for expectations in the area of broader impacts across not only the directorate but across the foundation.

5. The COV recommends that the management team keep a close eye on the administrative burden of the EF and EF-associated activities on the program officers and develop an FTE distribution plan to assure a reasonable distribution of this burden.

C. 4.

1.Conduct comprehensive "EF" COV reviews to better enable the Committee to develop a coherent picture of the EF portfolio and address more fully Division-wide issues.

2.Explore the possibility of expanding the AToL practice of fostering collaboration amongst PIs submitting proposals with overlapping goals and scope.

C. 5.

The text of C. 5. constitutes a set of recommendations.

DIVERSITY DOCUMENT

Committee of Visitors
DIVISION OF EMERGING FRONTIERS
Directorate for Biological Sciences
National Science Foundation

September 11-13, 2006

This document describes the diversity, independence, and balance represented by members of the COV, and the resolution of real or apparent conflicts of interest.

The **2006** Committee of Visitors for the Division of Emerging Frontiers (see attached list) was composed of 8 members, including Dr. Christopher Comer, who represented the BIO Advisory Committee. Three of the members are female, and three members are from an underrepresented minority. Members currently work in seven different states and the District of Columbia, including Illinois, Michigan, Utah, Wyoming, Maine, Ohio, and California. Seven members are from academic institutions and one is from government.

All files presented to the committee were first scrutinized for possible conflicts with committee members. All conflicts were identified so that committee members would be aware of which files they could not review. Committee members were advised about confidentiality and conflicts of interest both prior to arriving at NSF and at the inception of the meeting. Conflicts issues during the meeting were considered and adjudicated by the division conflicts official.

James P. Collins
Assistant Director
Biological Sciences